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SCIENCE AND FOREIGN POLICY

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Coming Next

"West Germany," by Hans Kohn, distinguished historian at City College of New York and author of many books, including *German History: Some New German Views* (Boston, Beacon Press, 1954) . . . in the September-October issue of the *Headline Series* . . . appraises postwar political and economic developments in the country which twice during this century sought to dominate Europe. . . . Has Germany changed since 1945? . . . What role will it play on the Continent? . . . in world affairs?

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Democracy as measured by 20th century practice in the United States has had the benefit of a long partnership with science, not a long record of hostility. The conservationists of the Progressive Era profoundly believed that only a government informed by science could rule justly in the public interest. If their belief was too simple, the experience of the nation has nevertheless been in their favor. A democracy that has in fact enjoyed the results of science has been more tolerable, more humane, and more able to fulfill its responsibilities to its people. After the industry of the country and the military forces of the world came to draw their power from research technology, a government without considerable scientific competence could not have governed at all. During a century and a half, science has not only contributed to the power of the government but to the ability of the people to maintain their freedom.

—A. Hunter Dupree in *Science in the Federal Government* (Cambridge, Mass., The Belknap Press of Harvard University Press, 1957).

In the conditions of modern life, the rule is absolute: the race which does not value trained intelligence is doomed.

—Alfred North Whitehead

Science and Education: U.S. and U.S.S.R.*

by Robert E. Marshak

On August 6, 1945 an atomic bomb was dropped on Hiroshima. Within days a second A-bomb was dropped on Nagasaki to persuade the wavering Japanese government to surrender. The war was over and the United States was master of the world.

To the public everywhere, this was the hour of triumph for American science, climaxing a long series of successes such as radar, the proximity fuse and other developments. For American scientists, who had urged our military leaders not to drop the A-bomb on inhabited areas, the hour of triumph had come in a harmless test several weeks earlier when the first A-bomb lit up the heavens above the New Mexico desert. Be that as it may, the end of World War II saw the United States in a position of world leadership and American science the mighty bastion of a victorious and powerful nation.

Twelve years later the U.S.S.R. hurled its first Sputnik into outer space. Within a month a second and larger Sputnik was fired. From a state of devastation and inferiority in 1945 the Russians had forged ahead of us in the very important field of

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* Reprinted with permission from the *Bulletin of the Atomic Scientists* (February 1958), 5734 University Avenue, Chicago 37, Illinois.

missiles. This is an extraordinary development and the fact that it is not surprising to some of us scientists does not make it any less remarkable or challenging.

Why the Change?

What has happened during the short span of 12 years? How have the Russians made such rapid progress? The first point is that the Russians are determined to outstrip the United States in science and in all the arts of peace and war which are based on modern scientific developments. When my colleagues and I toured the nuclear research laboratories in the U.S.S.R. in May 1956, we noted the same personal dedication to the task at hand, the same emphasis on speed rather than cost, the same unlimited financial support for facilities and equipment which we ourselves had known at Los Alamos during World War II. It was clear that scientific research in the Soviet Union was being pursued with an urgency which was reminiscent of a wartime operation and that the objective was to overtake American science in its great diversity, its high quality, and its magnificent sweep. If this great sense of urgency prevails in such basic research fields as high energy nuclear physics, with which I am connected, how much more intense must be the crash programs in the atomic weapon and missile laboratories?

No Efforts Spared

Lavish provision for new up-to-date laboratories and the most modern experimental equipment is essential but it will not guarantee scientific research of high quality. It is also necessary to attract talented persons into the fields of science and engineering, to insist on high educational standards, and to inculcate the proper attitudes toward basic research.

The U.S.S.R. is certainly sparing no effort to induce the most talented youngsters to prepare for scientific and engineering careers. The stipend of a Russian university student equals the salary of a worker. All students who show talent in the sciences

Photo and caption, courtesy of *Look Magazine*

A CLASS IN PHYSICS AT A SOVIET UNION HIGH SCHOOL

are encouraged to receive more advanced training. Those who become professional scientists are handsomely rewarded both with material benefits and with status in the community.

As a result of such a policy, Soviet scientists form an elite whose scale of living stands in extreme contrast to the still low living standards of the general populace. It is therefore not surprising that of the 16,000 students at Moscow State University, 2,000 are majoring in physics. It is also not surprising that in the five-year period from 1951 to 1956, for which statistics are available, the number of graduate students in physics has tripled. This is in

contrast to the United States where the number has remained stationary. It is probable that the number of doctoral candidates in physics is now greater in the Soviet Union than in the United States.

Quality as Well as Quantity

Granted that the Soviet Union is turning out large numbers of scientists and engineers, how good are they? The answer is that their quality is generally high and, in certain fields, superior to the United States. The Soviet Union has developed an educational and technical training system which maintains high standards. It must be realized, of course, that the strong emphasis on science and mathematics in Soviet education and the strictness of the high-school curriculum are not Russian innovations. In most European, as well as non-European, countries the high-school curriculum is equally exacting. We Americans must realize that our schools are departures from the norm and differ from those throughout the rest of the world. Somewhere along the line the American people were persuaded that a system of free and universal education can only be implemented by a lowering of academic standards, by hiring some teachers who have a superficial knowledge of the subject matter which they are supposed to teach, by allowing students to eliminate science and mathematics from their curriculum, and by permitting the parents to interfere with the development of special programs for talented children.

There has always been a strong engineering tradition in Russia and at the present time, in some areas, the educational standards in engineering are higher than in the United States. For example, the average Russian electrical engineer takes more mathematics and basic physics in his curriculum than his American counterpart, and as a result appears to be more independent, creative and critical than the average American electrical engineer.

Moreover, these highly talented engineers receive higher salaries and enjoy more prestige in laboratories where basic research is carried on than in industrial laboratories. In my own field, physicists must design and construct the large cyclotrons, synchro-

trons and other types of high energy accelerators because engineers with the necessary training do not exist or, if they do exist, they are employed in more lucrative industrial positions. Is it then surprising that Russian engineers have constructed the largest accelerator in the world, and that they have achieved the technological breakthrough in the missile field?

Science Mobilized

It is evident, therefore, that the Soviet Union is not only providing new up-to-date laboratories and the most modern experimental equipment for its scientists and engineers. It is also insisting on high educational standards and, by multitudinous devices, attracting persons of the highest intellectual caliber into the scientific and engineering fields. Superimposed on this system is a political dictatorship which is intent on rapid industrialization of the country and on the development of a modern technology which is superior to that of the United States. This mobilization of scientists and engineers achieves results in the absence of political freedom and, under Stalin's regime, even in the absence of scientific freedom.

In Stalinist Russia, technological advance was extremely rapid for at least two reasons. The first reason is that large technological developments depend almost as much on organization and mobilization of resources as on the application of scientific brainpower. Stalin did not allow himself to be disturbed by interservice rivalries, by conflicting claims of industrial and government laboratories, or by division of authority at the highest government level.

Freedom Even Under Stalin

The second reason is that sciences like physics, mathematics and chemistry, which are at the basis of modern technological development, were allowed some freedom, even by Stalin. The biological sciences and, even more, the social sciences were badly damaged by the Communist party line imposed by Stalin. However, the natural sciences, which include mathematics and physics,

while not completely immune to political pressures under the Stalin regime, enjoyed some measure of intellectual freedom. While the Communist physicist Dmitri Blokhintsev, who is now director of the new international nuclear physics laboratory outside Moscow, devoted himself to "unmasking the idealistic and agnostic speculations [Copenhagen school] on the basic problems of quantum mechanics," non-Communist physicists proceeded to apply the Copenhagen "brand" of quantum mechanics to the construction of A-bombs, H-bombs and atomic power stations. Realist that he was, Stalin refrained from exiling these heretical physicists to Siberia.

Importance of Freedom

And now we come to the crucial point. Basic research in science cannot flourish without full scientific freedom. Scientific freedom implies that the scientist is free to choose the subject matter of his own research and is not compelled to work on problems in which he has no interest. Scientific freedom means that the scientist can draw the conclusions to which his investigations lead without subjecting them to the requirements of some nonscientific authority. Scientific freedom requires openness of communication, through books, periodicals and personal contacts. Now the interesting thing, and in many ways I consider this the most challenging of all the developments which have taken place, is that scientific freedom has essentially been re-established in the Soviet Union since Stalin's death.

We obtained direct evidence of a marked improvement in the scientific climate in the Soviet Union during the course of our visit in 1956. The first and obvious change was that all scientists formerly in disgrace or under arrest had been rehabilitated and that all the brilliant scientists who had been in trouble had been returned to positions of leadership. The second change was that the rigid mobilization of Russian scientists to work on war projects had apparently been discontinued. We were told that since 1954 Soviet physicists were no longer required to work on radar,

rockets or nuclear weapons, and it was evident that many of the luminaries in Russian physics were working on the basic problems at the frontiers of our science. It was also evident from our discussions with the Russian physicists that not even lip service was being paid any longer to the role of dialectical materialism in the development of modern physics.

Finally, in so far as openness of communication is concerned, it was clear that a very liberal policy of declassification of basic research had been adopted, that the usual exchange of scientific and technical information with foreign scientists was allowed, and that freedom of scientific criticism was regarded as a virtue. Indeed, we were amazed at the vigorous and uninhibited discussions which took place at the Moscow conference which we attended, where young Russian physicists did not hesitate to call to task distinguished academicians if points of difference arose.

On the basis of our visit to the Soviet Union and of our personal and scientific contacts with Russian physicists since that visit, it seems safe to assert that Russian physics is now almost as free as American physics. This newly established scientific freedom is not to be confused with political freedom, which is still essentially nonexistent. However, we must face up to the fact that in the strange world of the Soviet Union, the essential ingredients of scientific freedom have been re-established, at least in those scientific fields which are primary for the technological revolution now taking place and for the ultimate security and well-being of a modern nation.

Russia's New Challenge

It is this fundamental change in the scientific climate in the Soviet Union which is the most challenging aspect of the entire situation. Suddenly to be given the moral and spiritual conditions for independent and creative research has filled Russian scientists with optimism and self-confidence for the future. It is the combination of this post-Stalin re-emergence of scientific freedom plus the continuation of strong financial support for scientists and

engineers, their laboratories, and their education which constitutes the nature of the Soviet scientific challenge. In the absence of scientific freedom, it is possible to bring to a successful conclusion a sputnik or an A-bomb project provided a sufficient effort is made and the raw materials, the industry and a corps of well-qualified scientists and engineers are in existence. It is much more difficult to make the basic scientific discoveries which underlie these applied science and engineering developments. Basic research is a much more delicate flower and can only flourish under proper conditions of light, air and absence of external compulsion. In the long run applied science and engineering will become repetitious and second-rate if they are not vitalized by the new discoveries of basic science. We have clear evidence that the Soviet government now understands that genuine scientific progress demands scientific freedom.

How Is U.S. to Meet It?

How are we to meet this Soviet scientific challenge within the context of our American democratic society? There would be little point in exerting ourselves if the Russian challenge could only be met by surrendering our democratic values and adopting the totalitarian way. I believe that the massive Russian challenge can be met in our own American way, but before suggesting concrete remedial measures, it is necessary to make a frank appraisal of the scientific picture in our country at the present time.

The picture is far from black. One measure of the strength of basic science in a country is the number of Nobel prizes awarded to scientists in that country. Since World War II, American scientists (including those who have taken up American residence) have won 17 Nobel prizes whereas the Russians have won 1. It would be wrong to deduce from these figures that American basic science is 17 times as strong as Russia's, since the gap is narrowing so rapidly. However, neither are we justified in suddenly acquiring an inferiority complex as a result of the sputniks and asserting that Russian basic science has surpassed ours on an over-all basis.

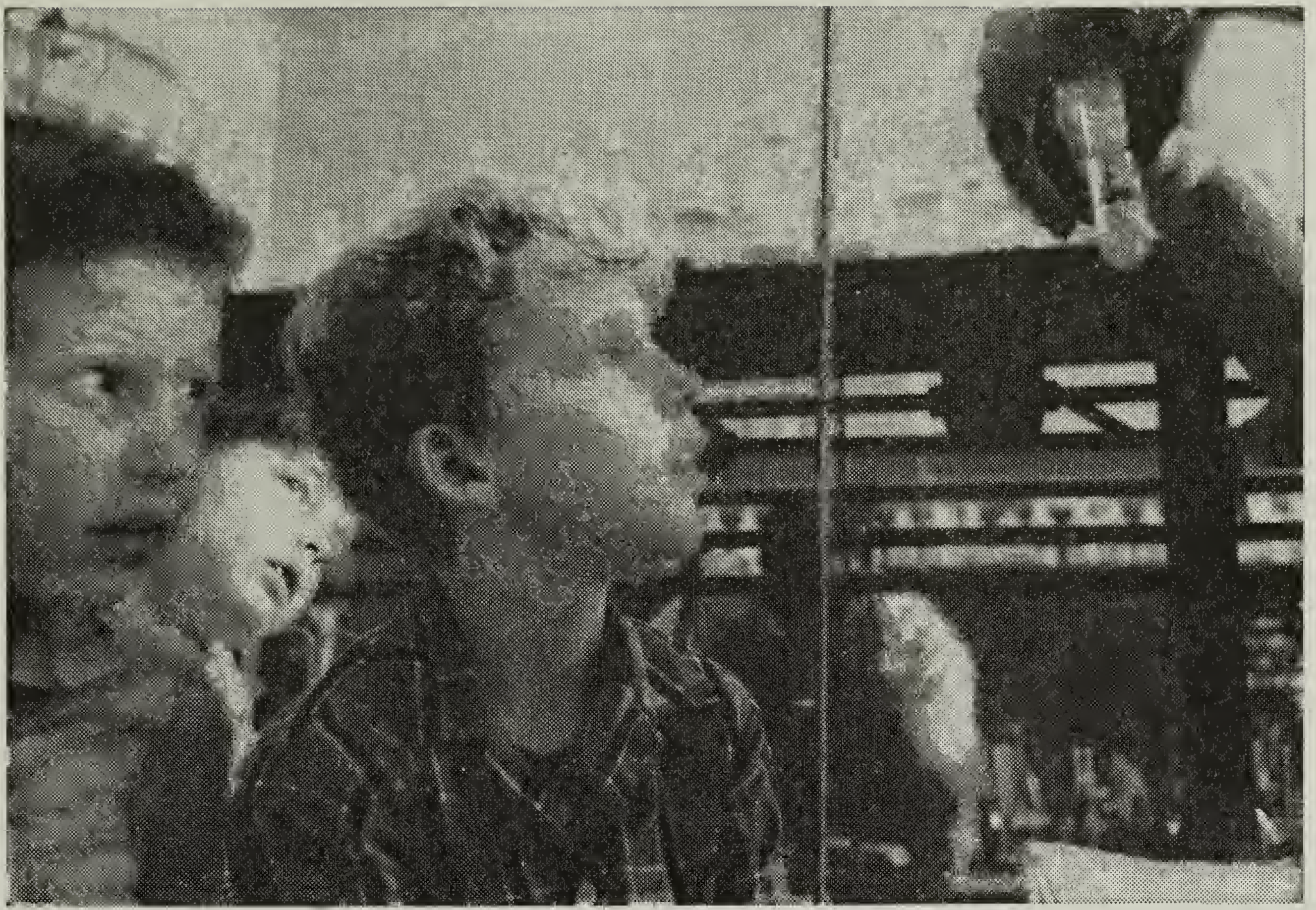

Photo and caption, courtesy of *Look Magazine*

AN ELEMENTARY-SCHOOL SCIENCE CLASS IN THE U.S. VISITING A JUNIOR COLLEGE CHEMISTRY LABORATORY

The American lead in basic science, precarious as it has become, has been due to a long tradition of scientific freedom in this country as part and parcel of our democratic heritage. There have been occasional lapses like the dismissal in 1953 by Secretary of Commerce Sinclair Weeks of Dr. Allen V. Astin, director of the National Bureau of Standards, for his adverse scientific recommendations on battery additives; and the withdrawal by former Secretary of Health, Education and Welfare Oveta Culp Hobby in 1955 of funds from medical researchers in whose files some derogatory information was found. And, of course, there was the

brief but terribly disturbing era of mistrust when the case of J. Robert Oppenheimer was a *cause célèbre* and the late Senators Joseph R. McCarthy and Patrick A. McCarran rode roughshod over scientists and intellectual "eggheads" in general. But, by and large, the American scientist has been free for a long time, except during war emergencies, to choose the subject of his own research and to publish his results without approval by a nonscientific authority.

Material Support Necessary

Indispensable as is scientific freedom for the development of a healthy science, basic research will not prosper in the present day and age without powerful material support for laboratories and equipment, without the existence of an educational system of top quality, without the willingness of highly talented persons to engage in the pursuit and creation of basic science, and without the proper appreciation by the public of the value of science.

The first obvious weakness which has developed in this country is that the financial and prestige incentives are not such as to persuade the scientist or engineer to remain at the university where most of the basic research is done and where all the training of new scientists and engineers takes place. Increasing numbers of scientists and engineers are leaving their university posts to accept more lucrative positions in industry.

Another weakness which has developed is that while the quality of scientific training in our graduate schools is high, the same cannot be said of the training of our engineers or of the scientific training in our high schools and colleges. A third weakness is that many of our universities do not have sufficient funds to provide the new up-to-date laboratories and the latest equipment which are needed for modern scientific training and research. Many colleges and universities are now faced with the problem of inadequate laboratory facilities to train the additional science and engineering students.

A fourth weakness is that many young people with the necessary

talents do not embark on scientific and engineering careers for financial or other reasons because the American public is not sufficiently well informed about the importance of science and engineering for the national welfare and security. At least one-third of the upper quarter of the students graduating from high school do not go on to college, and many of these are certainly potential scientists and engineers.

Lack of Funds and Personnel

A fifth weakness is that government laboratories, where certain coordinated research projects must be carried out, are in a poor competitive position with respect to industry in terms of attracting scientific manpower. The rigid Civil Service system prevents most government laboratories from recruiting the top scientific talent which they need to head up their research projects.

A sixth weakness is that in many instances American industry is not fully utilizing its scientific and engineering manpower. Russia is training five times as many engineering aides, laboratory assistants, junior draftsmen and designers as we are in the United States, and until more of these men are available, we can hardly blame a company for relegating a highly trained engineer to the role of a draftsman. And, last but not least, sufficient funds are simply not being provided for basic research in the sciences and engineering. I have personally served on national advisory committees during the past year which have approved excellent plans for research that are being held up for lack of funds.

What We Can Do

It is clear that the weaknesses which have developed in the scientific and technological picture within the United States are so formidable that all levels of government, industry, education and the general citizenry will have to undertake a coordinated and sustained effort in order to correct the situation.

It will be necessary to raise the salaries of the science and engineering professors so that they will stay at the universities. It

will be necessary to train better teachers of mathematics and science and to keep these teachers in the high schools and in the colleges by financial and other inducements. It will be necessary to re-examine and strengthen our scientific and engineering curricula and to provide special training and opportunities for the young people who are talented in mathematics and science.

It will be necessary to provide funds for colleges and universities so that they may enlarge and improve scientific and engineering facilities in the form of buildings, laboratories and equipment. It will be necessary to provide large numbers of scholarships for science and engineering students on the undergraduate and to a lesser extent on the graduate level so that all young people who desire, and are qualified, to embark on scientific and engineering careers, may do so. It will be necessary to set up more government laboratories on the pattern of the Los Alamos Scientific Laboratory (which is run by the Atomic Energy Commission through a contract with the University of California), so that Civil Service regulations will not interfere with the recruitment of the necessary scientific personnel.

It will be necessary to set up a reasonable number of technical institutes (in the form of junior colleges or through other mechanisms) which will train the many students with science aptitudes who, for one reason or another, either do not wish or are unable to undertake a four-year curriculum. This additional technical manpower will release a sizable number of more highly trained scientists and engineers for more responsible positions. And finally it will be absolutely essential to provide the increasingly large sums of money which are required to carry on basic research in the sciences and engineering. This means at least doubling the annual operational budget for basic research in science and engineering. In addition, capital expenditures must be made for some rather large facilities in science and engineering such as high energy accelerators, astronomical observatories, computational laboratories, specialized engineering laboratories, and so on.

But apart from the measures which must be taken in order to maintain our scientific and technological supremacy over the Soviet Union, we must realize that there are bigger issues at stake. Scientific supremacy or even the maintenance of substantial scientific equality is only a means to an end. It will not secure the peace, guarantee the survival of our democratic institutions, or assure our moral leadership of the world. Wise political, economic and human decisions will still be required to achieve these desired goals. And so let us get on with the task at hand. The early American pioneer had a sense of high adventure, but he was of a practical bent. Let us inculcate in our people a new pioneering spirit, a sense of novel and exciting intellectual domains to conquer, and we shall not have to fear for our scientific, cultural or political leadership. It is only by rededicating ourselves to the values of the mind and spirit that we shall be equipped to achieve our true national destiny.

Discussion Questions

1. In what respects is Russian education superior to that of the United States?

2. In what respects is American education superior to that of Russia?

3. Is it true that the Russians stress "basic research" more than we do?

4. In the future should we put our primary emphasis on training in science, or should our objective be a tougher all-round curriculum?

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VISUAL AIDS*

Happy Childhood. Produced in the Soviet Union in 1955. 48 min., color. Rental $15.00 from Alsher Films, 1311 19th Street, N.W., Washington 6, D.C. English narration. Film shows how Soviet education, from infancy to adulthood, emphasizes the care and attention given their youth.

The Search: Harvard University—(Inadequate School Facilities). Produced in 1955 by Columbia Broadcasting System, Inc.—Television. 25 min. Rental, apply Young America Division, McGraw-Hill Text Films, 330 West 42nd Street, New York 36. Demonstrates the new "shadow" technique by which researchers in a Massachusetts community follow the children through their school day to determine what is needed from the child's point of view. Teachers and parents are interviewed. Data is analyzed and recommendations are made.

The scientist is not only a researcher and an educator, he is also often a representative of the United States, as scientific spokesman in world gatherings and as technician in foreign-aid programs. Are our scientists well prepared for these roles that involve diplomacy? Are they helped or hindered by our foreign policy?

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* Unless otherwise noted, all films are 16 mm, sound, and in black and white. For information on rental of films, write to Audio-Visual Department, World Affairs Center for the U.S., UN Plaza at 47th Street, New York 17, N.Y.

Science and Diplomacy

by W. Albert Noyes, Jr.

Foreign policy in one sense has its origins at the grass-roots level, but in another sense the guidance of policy and the education in foreign affairs of the man in the street must filter from the top down. Even apparently unimportant decisions must be made with all of the relevant facts at hand, and mainly by persons accustomed through long training to understand the possible consequences of every move.

In a democracy the amateur may have a controlling voice when the specialist should be heeded. Nevertheless, democratic principles are at the very basis of our way of life, and to permit experts to operate without proper checks and balances could ultimately prove most dangerous for the nation.

While the broad outlines of foreign policy are determined by the Executive and reshaped by debates in Congress, there are areas where the application of broad divisions is not clear and definite. As I said on May 24, 1957, in accepting the Willard Gibbs Medal of the American Chemical Society: "We must distinguish clearly between the utilization of expert scientific knowledge to aid in broad foreign policy decisions and the development of foreign policy on matters which affect mainly science and scientists."

Diplomats of Science

Since 1950 American scientists have advocated the appointment of a high-level science adviser to the government in Washington who could guide the Administration in the intricacies of modern technology, which is having such a profound impact on this country's role in world affairs. In 1951 these proposals were in part implemented by the appointment of a science adviser and science attachés.

In 1955, however, the plan for scientific attachés was suddenly abandoned as an economy measure. Attachés and appropriations were withdrawn, and a science adviser who had been installed in 1951 was not reappointed. The Department of State refused to acknowledge that the plan had been abandoned but declared that "it was held in abeyance." It is interesting to note that in 1957 the United States had 500 military attachés assigned to our foreign missions—and not one scientific attaché. Commenting on the government's decision to give up science attachés, the *Chemical and Engineering News* said on January 9, 1956: ". . . the attachés report glowingly of their work and of the program's reception abroad. The ambassadors and other mission officers have been cordial and helpful. Some ambassadors relied directly on the science attachés for detailed advice and guidance on scientific matters affecting foreign relations. Good working relations were established between science attachés and other officers of the embassies with whom they frequently had to work on matters of common interest. . . . United States science attaché work found wide acceptance among scientists and others in foreign countries. . . . The scientists who have served abroad believe they have something unique to offer toward foreign relations."

Following the controversy over Russia's sputniks, a science adviser to the Secretary of State, Dr. Wallace R. Brode, formerly associate director of the National Bureau of Standards of the United States Department of Commerce, was appointed on January 13, 1958. One of his first duties was to recruit senior scientists to fill posts as science attachés in some of the most important

OPENING MEETING OF THE 'ATOMS-FOR-PEACE' CONFERENCE, GENEVA, AUGUST 8, 1955

Courtesy of the United Nations

Partial view of the audience of scientists at the Palais des Nations

embassies of the United States, posts which had existed between 1951 and 1955, but had been discontinued by the Eisenhower Administration.

Role of Scientists

A science attaché, as visualized by the Department of State, should be a man of stature who will represent United States

science at a high level. He is to be much more than a collector of information and a liaison man between the United States and the country where he is to serve. He would be a real diplomat of science who could hold his own in meetings of learned societies and academies. It is self-evident that such persons are hard to find and even harder to pull away from the laboratory, but they have an immensely important mission to perform in convincing the world that United States science is of high caliber and that it is not all concentrated on the production of instruments of war.

Let us look at specific instances of the part scientists play in low-level foreign affairs. There are many international scientific bodies in existence, but among the most important are the international scientific unions grouped together under the aegis of the International Council of Scientific Unions. There are no individual memberships in these unions, which have as their adhering bodies technical societies or national academies from many countries. In most countries these adhering bodies are governmental or semigovernmental in character, and the delegates to the meetings are more often than not official government representatives. This need not necessarily be true if the adhering body, as in the case of the United States, is not a government body, but in order to give official recognition to delegations, the United States representatives are often appointed by the Department of State even though they are chosen by the National Academy of Sciences.

Communist China Problems

Many Communist-ruled countries adhere to these unions, and this creates no particular problem as long as the governments of these countries are accorded full recognition by the government of the United States. When this is not true, as in the case of Communist China, serious problems may arise even though these are not the types of problems which lead to serious diplomatic incidents. For various reasons the government of the United States has not seen fit to recognize the government of Communist China, and this seems to be the clear intent of Congress.

Scientists, however, have for centuries considered science to be international, and short of actual war they believe it not only desirable but essential that there be a free interchange of ideas among the scientists of all countries. Some of the international scientific unions, indeed, have provisions in their statutes which prevent the holding of meetings in countries to which there is not free access of bona fide scientists from any country. Since the citizens of certain of the Communist regimes not recognized by the United States government may not enter this country, or at least may enter only by special permission which is often difficult to obtain, the meetings of some of these unions cannot be held in the United States. The Soviet government, by contrast, takes the view that scientists from any country whatsoever may attend the meetings of scientific unions when they are held in the U.S.S.R.

The resulting situation is serious in the sense that, by being unable to serve as host country on certain occasions, the United States loses scientific prestige to the Soviet Union. This difficulty, however, can be avoided by the simple expedient of not extending invitations to meet in the United States. A more serious problem arises when a Communist regime not recognized by Washington applies for membership in a scientific union, because at this point a United States delegation, if it followed our foreign policy, might feel it should not attend with representatives of such a regime. The question could even arise in some extreme cases as to whether or not the United States might be forced to withdraw from a scientific union altogether if some unrecognized regime were admitted to membership.

How Should Scientists Apply U.S. Policy?

Given these circumstances, one may legitimately ask the extent to which the broad foreign policy of the United States should be applied to low-level diplomacy such as we are talking about in the international scientific unions. Is the admission of Communist China to a scientific union an entering wedge to the United Nations or to any of its specialized agencies? If it is, then since

the United States is at present firmly committed to oppose the admission of Peiping to represent China in the UN, it is difficult for United States delegations to be present at meetings of scientific unions in which Chinese Communist delegates are seated. Since there are many qualified Communist Chinese scientists and since such boycotting of meetings would go against the fundamental beliefs ingrained in scientists by their training, awkward situations may arise. Many scientists feel so strongly about this matter that they may refuse to serve on United States delegations, at least if these delegations are appointed officially by the Department of State.

It is not appropriate here to discuss the validity of our foreign policy with respect to the recognition of certain Communist regimes, but it should be clearly pointed out that if this policy of nonrecognition is carried down to the level of the working scientist, the United States may suffer diplomatically far more than the people and the Congress of this country realize, because the realm of intellectual activity is accorded a far more important place in many countries than it is here.

No Iron Curtain in Science

Even aside from the political question concerning the admission of Communist regimes to the UN there are sound scientific reasons for not excluding any of the great countries of the world from international scientific bodies. It is unthinkable that the values of certain physical constants should differ on opposite sides of an iron or a bamboo curtain, and that the names of the chemical compounds should differ from one country to another. No matter what barriers we may attempt to set up, the scientists of the world are forced to make agreements with each other on matters pertaining to the nomenclature and symbols of science. If a great country like Communist China were to be excluded either its wishes would be made known through its friends who are representatives, or we would have the impossible situation of an increasing failure

on the part of the scientists of one segment of the world's population to understand the scientific language of the other segments.

It would be unfair to say, however, that the scientists of the United States either favor or oppose the recognition of Peiping. Presumably a poll would indicate that they follow in a general way the feelings of other American citizens on this issue. It is clear, however, that our failure to recognize Peiping is a handicap to science, and that because it is a handicap to science we open ourselves to a criticism for which we have no very good answer.

Scientists and Foreign Aid

So much for foreign policy at the grass-roots level among scientists. There are also high-level policy decisions in which science plays an important part. For example, the foreign-aid program of the United States has changed in emphasis since the end of World War II and has passed through a phase which made it mainly a military support to our allies. This support was both of a purely military nature and of an economic nature, since allies, to be valuable to us, must have economies which could stand up under the strains and stresses of war. Admittedly the military aspects of our foreign-aid program cannot be neglected, because if we ever do have a war it will be hopeless for us to fight that war alone. At the same time we must take a long-range view of the international situation and realize that wars are not always won solely by armies, navies and air forces. It may be just as disastrous to allow some large country to fall under Communist domination without a fight as to lose some of our allies.

Peaceful penetration of the uncommitted non-Western nations is essential for the future of the United States, and this penetration will possibly be furthered by scientists and engineers more than by any other single group of Americans. There are sound reasons for this belief, because the non-Western peoples have their own histories of which they are proud, their own literatures, art and music and their own political and economic systems, which may

not easily be changed to Western models. At the same time they will become industrialized by one means or another, because only by becoming industrialized will they be able to provide the comforts necessary for a decent standard of living. An industrial economy not supported by a strong educational system, of which science must be an important part, and without research laboratories, will have small chance of survival. Public health, sanitation, agriculture, power and many other essential ingredients of modern life can be supplied only by a population which is well trained in science and in engineering and which respects the scientific point of view.

Russia's Penetration Through Science

There is ample evidence that the U.S.S.R. has clearly recognized the need for a peaceful penetration of other countries through science. We have many reports about the number of scientists and technicians who are being trained in the Soviet Union. It is quite possible that more are being trained than can be used at home, and some of them will be exported temporarily or permanently to aid underdeveloped countries. The United States has also recognized this problem, and under our mutual security program there are about 5,000 or 6,000 American scientists, engineers and technicians working abroad in addition to about an equal number of citizens of other countries employed under our program. Nevertheless, our scientific contribution is only a small fraction of our total foreign aid, and officials at the highest government levels should consider very carefully whether our effort in this respect is large enough to permit us to hold our own in the face of what the Russians are accomplishing.

Our Allies and Scientific Secrets

Thus it behooves this country for its own good to make scientific knowledge widely available throughout the world, even in coun-

tries which prefer not to join us as military allies. But we have a special problem concerning our military allies, for if they are to be of real value to us in time of emergency, they must be thoroughly trained in the use of the weapons which we may all have to use. This training implies that certain areas of secrecy about weapons can no longer be maintained. The allies of yesterday may be the enemies of tomorrow, and some countries which we now consider as allies were our enemies in open conflict only 13 years ago. Just how far are we justified, therefore, in making our development of weapons known to our present allies?

The answer to this question is perhaps more political than scientific, but let us bear in mind that our allies are proud peoples, that they will not be content to die on the battlefield while we carry out the research, the development and the production of weapons in our laboratories. It may be argued, of course, that future wars may be waged by push-button gadgets at long range, but this may not necessarily be true, and there may still be many small brush fires which will have to be put out and in which nuclear bombs will not be used.

Our allies have in general a high level of technical competence. They are willing and anxious not only to develop their own economies but to take an active part in the development of the instruments of modern war. Somehow a means must be found for taking them much more into our confidence than we have in the past and for providing a better integration not only of our military machines, but also of our educational systems at the scientific level. Indeed, we may have much to learn from our allies about academic standards, originality of thought and research in pure science, and they in turn may have much to learn from us about the application of science and technology to the problems of everyday life. This is not to say that the exchange of information and scientists does not already occur on a vast scale, but all too often there are barriers which prevent both the practical and spiritual integration of our programs with those of our allies.

Conquests of the Spirit

These are some of the problems scientists face in dealing with foreign policy. The list could be extended almost indefinitely. But there is one problem we have not discussed: this is the education of the scientist so that he can appreciate and understand the role he must play both collectively and as an individual on the world scene. It is trite to say that, after all, the scientist knows more about the humanities and the social sciences than the humanist and the social scientist know about science. Inevitably each individual is best trained in his or her own specialty, but knowledge is not sufficient to provide the incentive which we believe to be necessary. In all areas of American life, and perhaps particularly in science, we need persons familiar with foreign languages, with foreign peoples and with foreign cultures, so that they will be able and ready to carry their special knowledge and techniques to the far corners of the earth.

We must educate the American people to believe that worthwhile careers exist in all parts of the world and that it is our duty to send people wherever they are needed. In this respect we have much to learn from the history of the British. We do not have and we do not intend to have an empire in the sense that the British have had one for several centuries, but there are victories of the spirit, and we must frankly recognize that science cannot be ignored in furthering these victories.

Discussion Questions

1. Does the scientist have a role to play in American diplomacy?

2. To what extent and in what ways does United States foreign policy restrict the participation of American scientists in international scientific organizations?

3. Have American scientists taken an active part in international organizations such as UNESCO?

4. What contribution can scientists make to United States foreign-aid programs?

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Report on Technical Cooperation. Produced in 1954 for the United States Foreign Operations Administration. 36 min. Rental, free. Americans share their know-how in agriculture, health and education in India, Indochina, Libya, Afghanistan, Ecuador, Indonesia, Paraguay and Ethiopia. Foreign trainees in the United States learn skills in medical research, engineering and agriculture.

We have achieved a high level of technological development in the United States through effective use of our scientists and engineers. But the American public in general had not yet given much attention to scientists until the dramatic developments, highlighted by the invention of the A- and H-bombs and the sudden emergence of rockets, which made possible both earth satellites and intercontinental missiles. What is rocketry?

What Is Rocketry?

by Harold M. Schmeck, Jr.

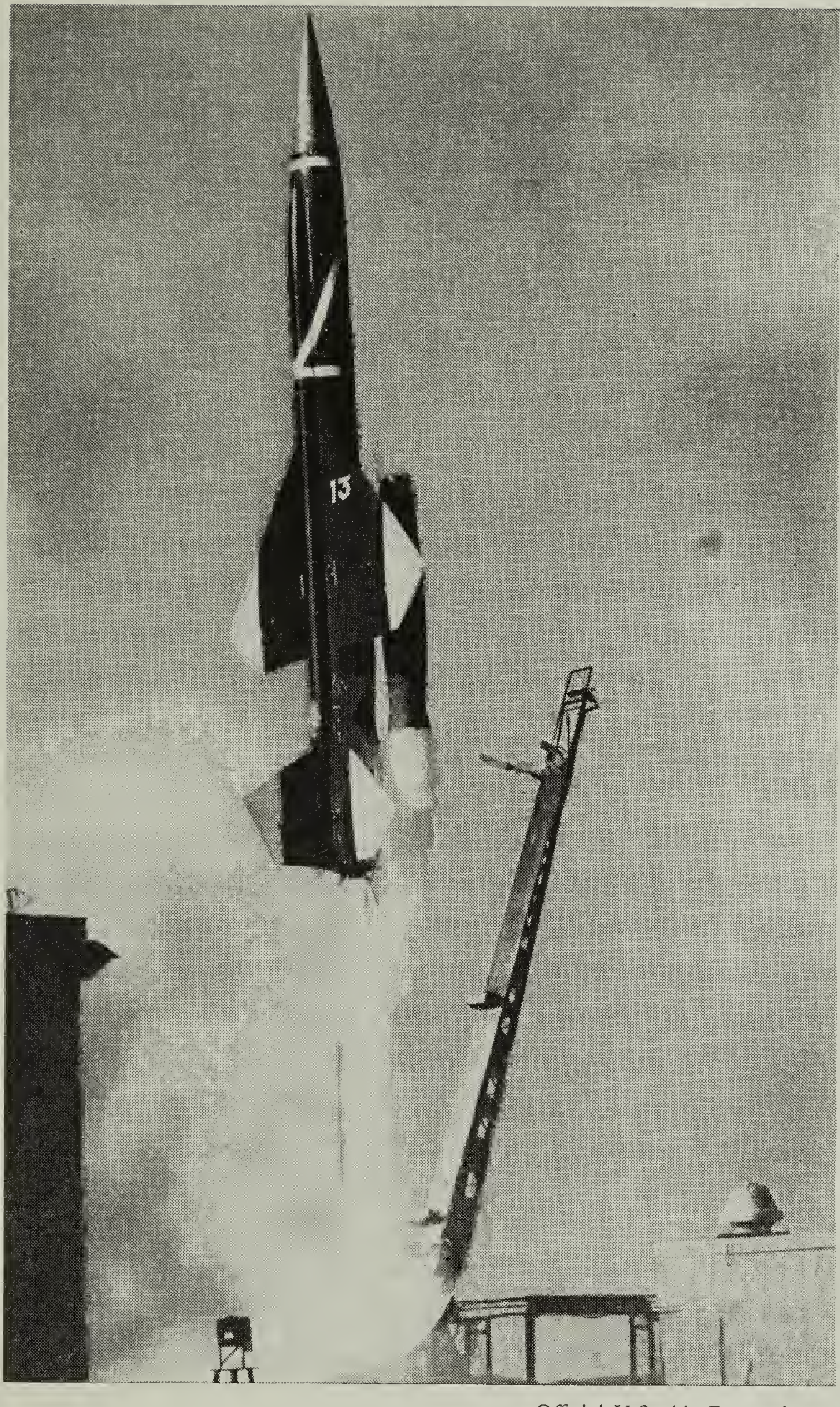
A ROCKET CAN BE SOMETHING AS SIMPLE AS a skyrocket or as complex as an intercontinental ballistic missile.

As weapons of war, rockets antedate the atomic age by many centuries. Only with the advent of city-shattering explosives like the atomic and hydrogen bombs, however, have their full potentialities come within man's reach.

Rockets Long Known

It is not definitely known who invented the rocket, although the Chinese are often given credit for using it first. "Fire arrows," which appear to have been conventional arrows powered by attached black-powder rockets, have been cited from a Chinese manuscript describing a siege which took place in the early 13th century.

By the beginning of the 15th century rockets were well known in Europe. They have had several periods of popularity as weapons since then, but during the latter half of the 19th century they were rather thoroughly eclipsed by the rapid improvement of conventional artillery.



Official U.S. Air Force photo

A Boeing IM-99 Bomarc — a ramjet-powered interceptor missile — goes hurtling into the air on a test flight from the Air Force Missile Test Center at Patrick Air Force Base, Florida

One of the pioneers of modern rocketry was Dr. Robert H. Goddard, whose developments in this country included liquid fuels and gyroscopic stabilizers for rockets. He stated the principle of multistage rockets as early as 1919. A recoilless launcher which he developed in 1918 was the prototype of the bazooka of World War II.

Many of his basic ideas anticipated the German V-2 rocket, which was the first supersonic long-range ballistic missile to be used extensively in warfare.

The Rocket's Thrust

In its simplest form the rocket is a tube in which the propellant burns, spewing its combustion products from one end. This causes a recoil of the rocket in the other direction. The recoil is called the rocket's thrust. The development of thrust does not require that there be any air behind the rocket. In fact the device works best in a vacuum.

Modern missiles can be driven either by rockets or by jet engines.

Jets, such as the turbojet and the ramjet, need oxygen from the atmosphere for the combustion of their fuel. It is for this reason that jet-powered missiles are often called "air breathing." Their need for atmospheric oxygen puts limits on the altitude and consequently on the speed such missiles can attain.

The rocket motor, on the other hand, is self-contained. It carries its own oxygen and therefore needs no external ingredients for combustion. It actually operates at peak efficiency beyond the atmosphere, where speeds can be attained far in excess of anything possible in the dense lower air.

Both jet, engine-powered and rocket-powered missiles have been under development for military use. The Air Force Snark, the world's first intercontinental guided missile, is a subsonic turbojet missile.

Rocket Propulsion and ICBM

In developing intercontinental ballistic missiles (ICBM's) such as the Atlas and Titan, however, rocket propulsion is used. These weapons are designed to shoot up beyond virtually all of earth's atmosphere in their bullet-like flight and to plummet down on target at speeds many times that of sound.

For excursions beyond earth's atmosphere, such as earth satellite launching or space travel, of course, rockets must be used.

Both jet- and rocket-powered missiles depend on the same fundamental principle. That is, the creation of thrust by expulsion of a jet of gas or other substance in the opposite direction.

Modern jet engines available for use in missiles are turbojets or ramjets, which burn high quality kerosenelike fuels. The fuels are burned with air taken from the atmosphere and compressed in the engine. A ramjet compresses its air directly by its high speed passage through the atmosphere. A turbojet uses a turbine inside the engine to do the compressing.

Two Types of Rocket Motors

Rocket motors can be divided into two main types: those which use liquid and those which use solid propellants.

The liquid fuel may be a "monopropellant," that is, a single liquid which will break up chemically with great release of energy under suitable conditions. These propellants often have the disadvantage of instability. They may tend to explode accidentally. Most liquid rockets use two components, a liquid fuel and an oxidizer. This oxidizer is often liquid oxygen, known to rocket men as "lox". Nitric acid is also frequently used.

Among the many possible fuels are alcohol, gasoline or related substances, aniline and hydrazine. Some combinations ignite spontaneously when brought together in the combustion chamber. Others must be ignited. The ideal propellant is one which releases the maximum amount of available heat into combustion products

of the lowest mean molecular weight. In developing modern high energy liquid propellants light elements such as hydrogen, lithium and boron have been given much attention.

Liquid-Propelled Rockets

Fuel and oxidant supplies, of course, are carried in separate tanks in the liquid-propelled rocket and must be pumped or otherwise moved to the combustion chamber. One method of doing this is to pressurize the tanks with an inert gas so that the liquids will be forced automatically into the feed lines when the valves are opened. This method is not usually acceptable, however, when the rocket's burning time is of considerable duration. Large rockets ordinarily require the use of fuel pumps.

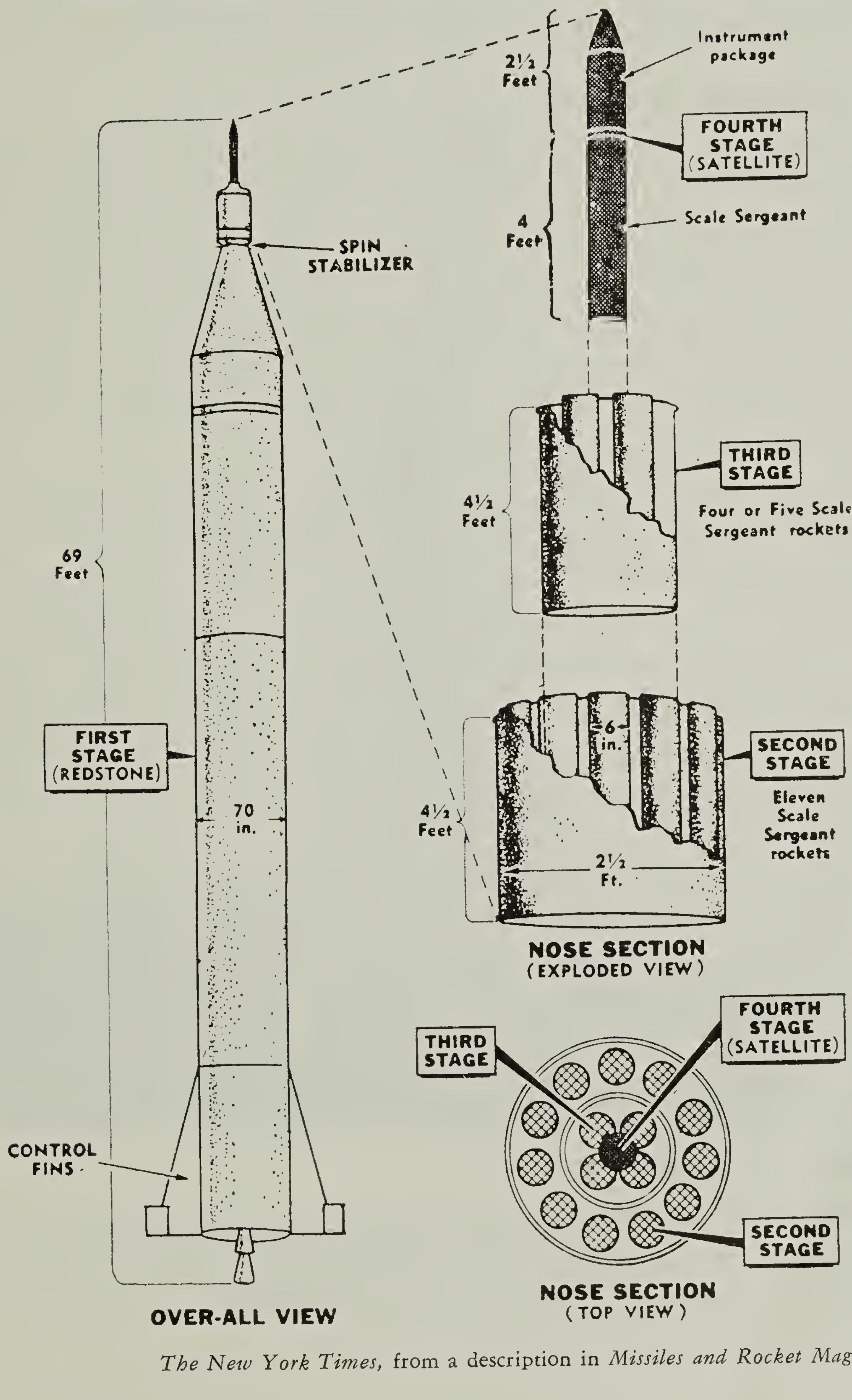
The liquids must be brought into the combustion chamber finely atomized and intimately mixed in the right proportions for the most efficient burning. Too great concentration of one substance in the chamber before the other arrives could produce a damaging explosion.

Because of the intense heat produced by the burning of the rocket fuel some method of cooling the walls of the combustion chamber and rocket nozzle becomes necessary. In some rockets a system of regenerative cooling is employed. This involves circulating one of the propellants as a coolant around the combustion chamber and nozzle before it enters the chamber. A further development is to make the walls of the combustion chamber somewhat porous so that some of the coolant seeps through as it flows around the outside of the chamber.

Liquid-propellant rockets can be highly complex devices. They have the advantage of offering good control of the rate of burning of the fuel and also of the precise point at which burning is cut off. The latter can be particularly important because the cut-off point determines the final velocity of the rocket and therefore can be used to control the range.

In huge military rockets liquid fuels can have the disadvantage of requiring the handling of highly corrosive, noxious or volatile

The Jupiter-C launching vehicle, which put Explorer I into orbit



The New York Times, from a description in *Missiles and Rocket Magazine*

liquids in fueling the rocket under field conditions. For the largest missiles, however, the separate handling of missile and fuel can be an advantage because of the great weight involved in the loaded instrument. This can be in the neighborhood of 50 to 100 tons.

Solid-Propellant Rockets

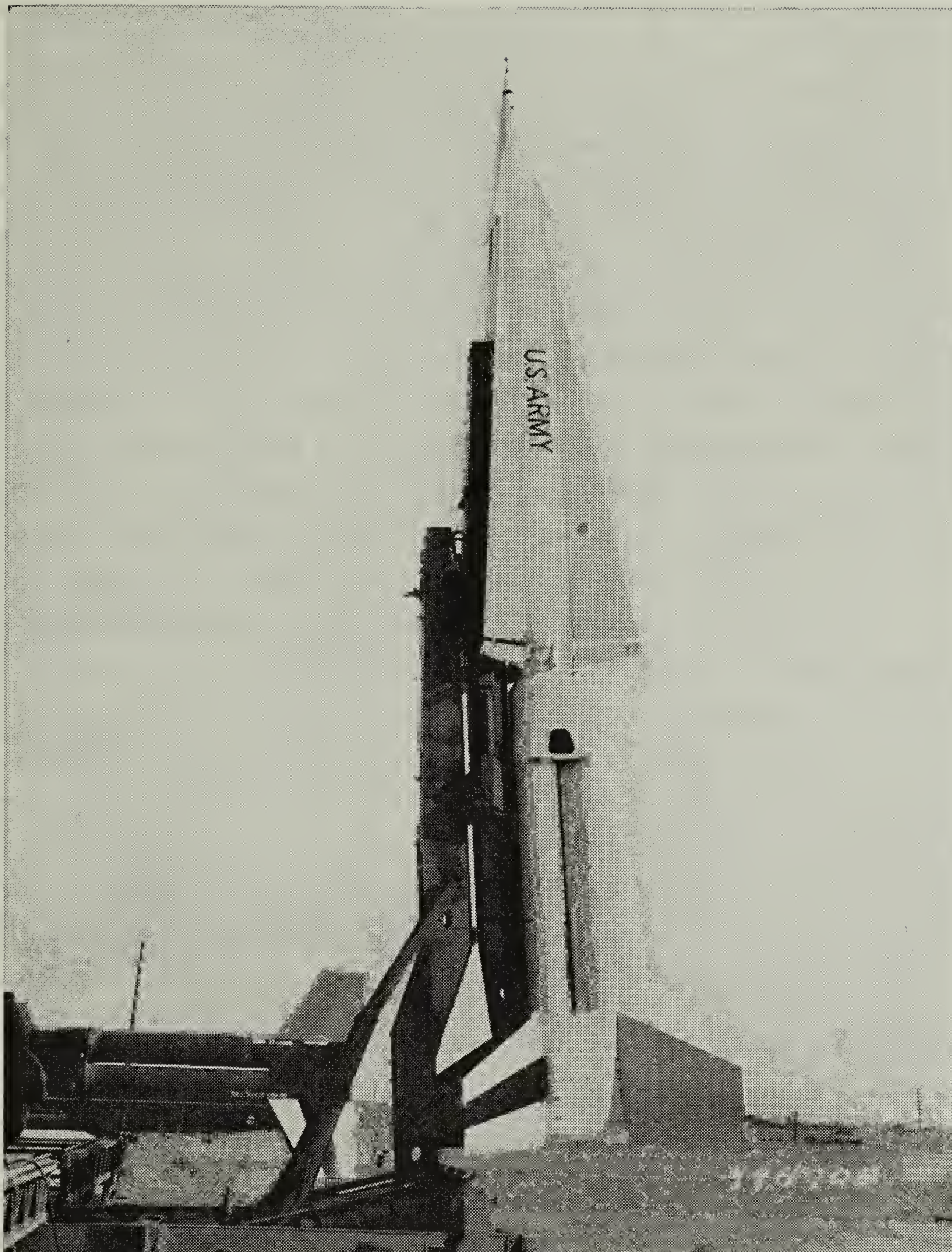
The solid-propellant rocket is the older and basically the less complicated of the two main types. The compartment in which the propellant is carried is also the combustion chamber. The need for moving parts and auxiliary apparatus such as fuel pumps is thus sharply reduced. The solid fuels may be more easily and safely handled than the components of a liquid system. Use of a solid propellant molded into the rocket case can add structural strength as well as ease of handling.

Development of both liquid and solid fuels is being pushed in rocket research. In some multistage rockets both systems are used. An example of this is the Jupiter-C rocket which launched Explorer I, the United States' first artificial earth satellite. Its first stage was powered by a modified Army Redstone liquid-fueled rocket engine. The second and third stages were groups of solid-propellant rockets, and the final stage, which also carried the satellite instruments, was powered by a single solid-propellant rocket.

Solid fuels have been long employed for small rockets and for boosters. In larger rockets they are considered particularly advantageous for use in such types as the Navy's Polaris, for which a 1,500-mile range is planned. The Polaris is to be fired from submarines, and therefore the prefabrication and easy storage possibilities inherent in solid fuels are extremely valuable.

Guidance and Re-entry

Of critical importance to the development of any missile system are the problems of guidance and reliability. For the long-range ballistic missiles which arch beyond the earth's atmosphere and



U.S. Army photograph

The Nike Hercules, shown at Army blockhouse area, White Sands, New Mexico. This antiaircraft missile uses a solid-fueled rocket for initial thrust.

back in their huge continent-spanning trajectories there is a third special challenge called the re-entry problem.

An ICBM can attain such tremendous speeds that friction with air molecules might cause it to burn up like a meteor when it plunges downward into the dense lower atmosphere on the last portion of its journey.

To prevent this, special materials and special design are needed. Basically the design problem is to convey heat quickly away from the rocket nose. It might be possible, for instance, to have the nose cone constructed of a somewhat porous material from which a liquid coolant would boil away during the few crucial moments of re-entry. Another possibility might be to design the nose so that a certain amount of its mass would be expected to melt away during the phase of greatest heating. An alternative would be that of using masses of a metal which conducts heat with extreme rapidity so that the heat of friction could be dissipated quickly enough beyond the nose.

The methods actually used in military rocketry are, of course, secret. In a report to the nation in November 1957, President Eisenhower said the United States had solved the re-entry problem. The Russians have also made claims which imply success in this vital matter. In both cases the method and the degree of perfection of the solution remain secret.

Variety of Missiles

The guidance problem depends necessarily on the type and function of the weapon involved, and missiles have become remarkably varied.

ICBM's and intermediate-range ballistic missiles (IRBM's) are planned to perform the functions of long-range bombers. They are surface-to-surface missiles designed primarily to hit stationary targets such as cities. Antiaircraft or antimissile missiles can be surface-to-air, air-to-air, or even underwater-to-air, missiles. The Navy's Polaris is planned as a potentially underwater-to-surface IRBM.

The methods of getting these missiles to their targets are correspondingly various. There are many varieties of radio and radar guidance and several types of homing devices. The latter are particularly important for missiles designed to destroy moving targets. Some, called passive homing devices, make the rocket follow a target because of their sensitivity to heat or other radiations which the target naturally emits. An active homing device, on the other hand, might be one in which the rocket emits a radar signal of its own and follows the target from which the signal bounces back.

The precise details of any guidance system are almost always secret because understanding the method used is often half the battle in designing countermeasures to jam or confuse it.

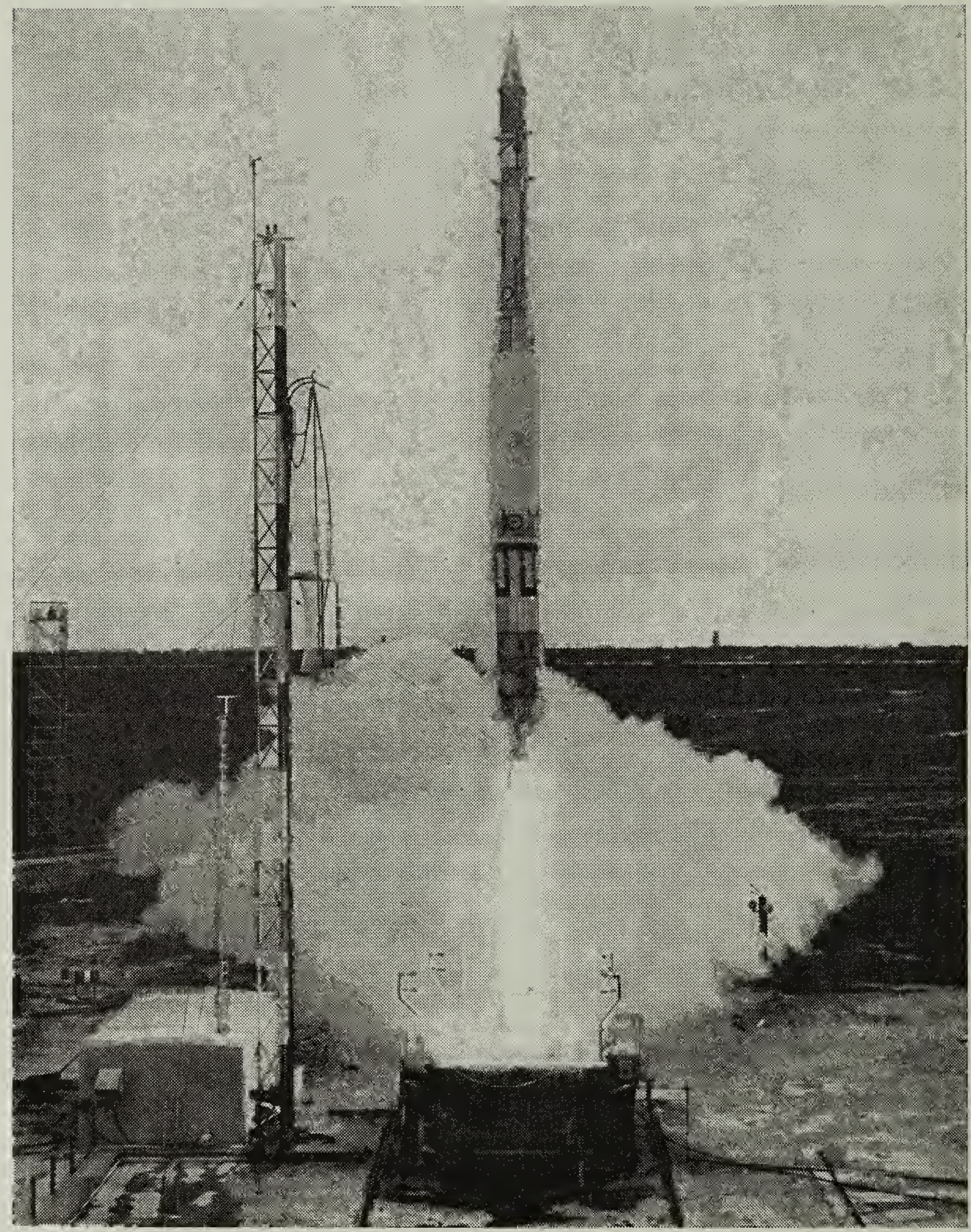
Inertial Guidance

There are methods, such as inertial guidance, which seem virtually impossible to jam. Inertial guidance uses what is called a stable platform. This has an orientation in space which is fixed and held by gyroscopes. The system is based on the elementary fact that any change in the motion of a body is in fact an acceleration. Motion therefore can be sensed by sensing the acceleration. The system uses accelerometers to measure the missile's every change of direction or velocity in three planes. Computers use the acceleration data to determine velocity and, from that, distance traveled.

Inertial guidance does not require any outside contact with the missile after it is launched. It does require, of course, that the exact location of the target be known and given to the computer before the launching. Its usefulness is therefore largely restricted to missiles aimed at fixed targets of known location, such as cities.

For the IRBM and the ICBM the precision required seems staggering. It has been estimated that an error in direction of only one degree at launching of a ballistic missile could produce an error of 25 miles at a destination 1,500 miles away. Such missiles travel at speeds measured in thousands of miles per hour, yet an

THE ROCKET WHICH PUT A SATELLITE INTO ORBIT



Official U.S. Navy photograph

The Vanguard, driven by both liquid and solid propellant rocket-motors, leaving launching pad at Cape Canaveral, Florida

error of about one mile per hour could result in an error of a quarter mile over a target at a 1,500-mile range.

Advantages of Missiles

Missiles have certain obvious advantages over either artillery or manned bombers. They have a much greater range than artillery and can carry warheads that would be beyond the capabilities of any conventional gun. They can accept conditions impossible to a manned bomber and do not involve the risk of a valuable and highly trained crew with each flight.

They pay for some of their advantages by the penalty of not having a pilot on board to take emergency measures if something goes wrong.

Rockets are subjected to accelerations which make every component on board strain with several times its normal weight. They may develop severe vibrations from the huge power of their motors. In some cases the motors may develop thrusts equivalent to well over a million horsepower before cut-off. The missiles must be able to stand extremes of temperature and the shearing forces of fast moving layers of air at some altitudes.

Problems of Reliability

Designers have to watch the weight of rocket components more fanatically than a fat man watches his calories, and yet each component of the rocket has to have extraordinary reliability.

An expert on the subject of reliability has pointed out recently that each vital component of a missile decreases the system's over-all reliability by its own reliability factor. That is, the over-all reliability equals the product, not the average, of the reliability factors of its components.

Take, for example, a relatively simple missile with only 100 essential parts. If each component is 99 percent reliable the missile will have an over-all reliability of only 36.5 percent.

Such figures give an idea of the accomplishment involved in sending a complex multistage rocket aloft to set an artificial

satellite in a stable orbit hundreds of miles above earth; or in firing a large military rocket successfully over a range of hundreds of miles.

End of Road — or Stars?

Today, world interest in rockets seems about equally divided between the devastation which they promise as carriers of hydrogen-bomb warheads and the less predictable rewards they offer as a means of travel beyond the confines of our planet.

That rockets will increasingly shape world history is not to be doubted. What this shaping will be is up to mankind, but the rocket's potentiality is clearly great enough to take the human race either to the end of its road or to the stars.

Discussion Questions

1. Will rockets ultimately be a force promoting war or peace?
2. What will be the effect of solid fuel rocket progress on global strategy?
3. How much emphasis should the United States put on rockets and missiles (a) for military use; (b) for peaceful research?
4. What point is there in sending a rocket to the moon or to the other planets?

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Guided Missiles. Produced in 1954 by the Department of the Army. 26 min. Rental, free, from Signal Officers at Governors Island, New York; Fort Meade, Maryland; Fort McPherson, Georgia; Fort Houston, Texas; Fifth Army, 1660 East Hyde Park Boulevard, Chicago; Presidio of San Francisco. Shows research and development programs on missiles, with shots taken miles in the stratosphere which spell with dramatic impact the mystery and unbelievable power of the guided missile.

Our first reaction to the launching of Russia's Sputniks I and II was one of fear mixed with regret that a supposedly backward country had spurted ahead of the United States. Now that we have satellites of our own, we are better prepared to consider the constructive, as well as the destructive, aspects of earth satellites.

Earth Satellites and World Affairs

by Robert K. Plumb

THE LAUNCHING OF THE FIRST KNOWN ARTIFICIAL satellite of the earth on October 5, 1957—after which date the skies began slowly to acquire more man-made objects in orbit—was a step as dramatic as any that man has taken in his long evolution.

The successful first launching was not unexpected. The development of big military rockets put in the hands of man the ability to do a job whose fundamentals were laid out over three centuries ago by the German astronomer, Johannes Kepler, who in 1609 formulated the laws of planetary motion. Half a century later in 1686 Sir Isaac Newton arrived at the concept of gravitational attraction between bodies, concluding that it is in direct proportion to the product of the masses and varies inversely as the square of the distance between them. This explained why bodies could stay in elliptical orbits, speeding and slowing at near and far points of their travels through space, around a bigger mass.

Launching a Satellite

Dr. Robert H. Goddard, early in this century, made detailed studies of rockets. But the best skyrocket vehicles available then could not develop enough thrust for each pound of fuel carried to make it possible to put a satellite in orbit. Not until improved

fuels along with better combustion chambers and extremely accurate rocket guidance became available did the artificial satellite become a possibility, and then a reality, visible in morning and evening twilight to the awestruck earthbound.

The big rockets were capable of lifting a satellite payload, a few hundred pounds, up to 100 miles or more above the surface of the earth, where air resistance is very low. Then they could accelerate the load up to 5 miles a second (some 18,000 miles an hour) and aim it closely along a path tangential to the surface of the earth. The centrifugal force of the speeding satellite balances the gravitational pull of the earth on the satellite in orbit. The satellite continues its travels in a great ellipse until the tiny amount of atmosphere present at its nearest approach to earth slows it. The first satellite, Sputnik I, launched by the Russians on October 5, 1957, probably burned up like a shooting star during the first week of January 1958, when it plunged into the earth's atmosphere, Soviet scientists estimated. The first American satellite, the Explorer, launched on January 31, 1958, travels in an elliptical path varying in altitude from 200 to 1,700 miles (at a speed of about 18,000 miles an hour). It weighs much less than Sputnik I, but early estimates had it that Explorer might last several months or perhaps even several years.

What Can We Learn from Satellites?

Most of the early experiments with satellites depended upon visual and radio observations of the paths they took and the alterations of these paths with the passage of time. Deductions were made about the density of the very thin air at the closest approach of the speeding satellites. That is, measurements of the rate of a satellite's acceleration as its orbital rate increases when it comes in close tell how much air is left at the known satellite altitude. Other observations reveal the changes in the satellite orbit on successive passes around the earth. The changes may be due to "lumps" inside the earth which alter the gravitational pull. Similarly the shape of the earth, which is slightly flattened

at the poles, may be analyzed by observing how the satellite changes its path in successive passages around the earth. These experiments may be made with either radio or visual observations. Analysis of signals received from the radio beacon carried in the satellite may help reveal the amount of electrical charge in the "ionosphere"—the electrically active layers some 25 to 250 miles above the earth's surface. Refraction of the radio signal passing through ionized space (which gives a clue to the amount of ionization present) is measured for this experiment.

A Look into the Future

A host of future experiments to study the earth, space, the relations between the earth and the sun, and to help man understand the solar system and what lies beyond are planned. Satellites will be designed to carry particular scientific equipment in order to make particular scientific determinations.

For example, the earth is constantly being bombarded with radiations as well as with particles from the sun and from other stars in space. But a relatively thick blanket of air, close to earth, filters the incoming energy. Probably much of it is absorbed in upper atmospheric levels before it reaches earth. Thus the scientific investigator bound to earth gets a dim picture of the signals sent to earth from the sun and the other stars. His equipment can be lifted up part way in a balloon for experiments, or even up 200 miles for a brief time in a rocket.

A satellite, however, will provide a stable laboratory in space, relatively permanent and precisely located. From such a platform, incoming ultraviolet radiation from the sun can be measured over a long period. Science might learn whether the sun's output is steady or, if it is not, how it fluctuates. We might get a better understanding of how the sun influences the weather on earth as, indeed, it appears to do. In a satellite records of energy-rich cosmic rays, that travel from far in space, might be obtained. The cosmic rays could be studied for their message from outer space in their pure form, before they are altered by the earth's air blanket.

Biologists plan to send aloft many types of life to study the effects of radiations and the "weightlessness" of space travel on the bodily processes vital to life on earth. Satellites may be designed to experiment with the near vacuum in space, a condition achieved on earth only for short periods of time with elaborate and expensive equipment.

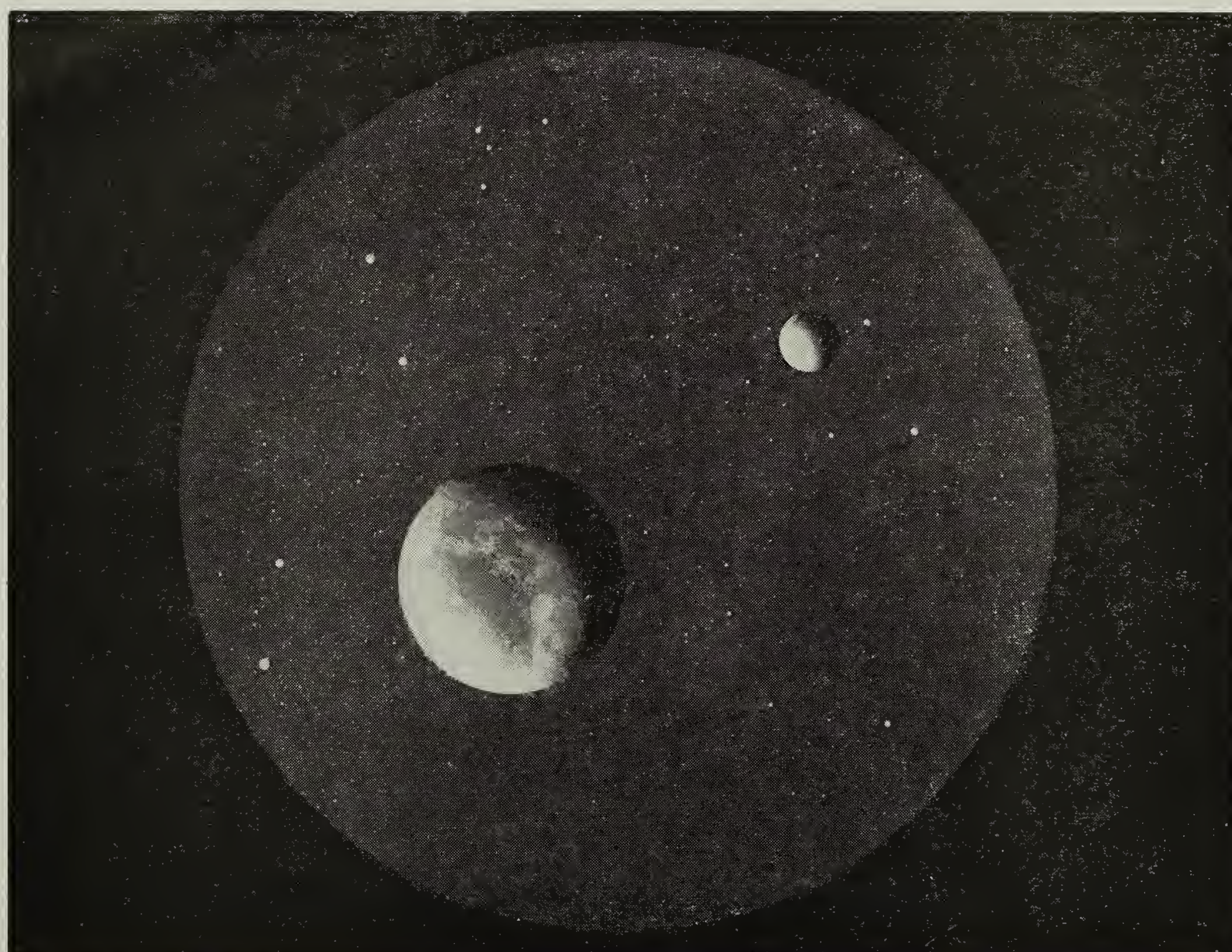
Investigation of Time

Another area for intriguing satellite experiment is an investigation of the characteristics of time as it enters into many mathematical relationships. Scientists propose to send aloft in a satellite a very accurate atomic clock and to compare the "readings" of this clock with the readings of a similar clock retained on earth. The question to which they seek an answer is whether relative time is affected by gravity.

And a telescope might be mounted on a satellite, some suggest. A telescope located high above the earth's restrictive blanket of air could observe distant stars and galaxies in much more detail than is possible with the largest telescopes on earth. The telescope might be either an optical one to take pictures or a radio telescope to observe distant galaxies by measuring the radio waves they give off. Perhaps, it has also been suggested, an observer might be placed up there to use the optical telescope. Perhaps television might relay optical observations back to earth.

From these scientific tests may come information of value to such practical affairs of earth as meteorology, communications and map making. In meteorology, satellites may provide for the first time a way to measure the large-scale cloud cover of the surface of the earth. Instead of sporadic reports from scattered stations on earth, an electronic or photographic record of the clouds, as a satellite traverses the globe, might be assembled. Coupled with new information about the radiations arriving at the top of the earth's atmosphere from the sun, far-reaching and accurate predictions of the weather might be achieved. Indeed, some scientists have speculated that a form of "weather control"

Earth and Moon Relationship



The Hayden Planetarium of the American Museum of Natural History

might be attained by man if knowledge of how the weather originates and what causes it to change can be obtained.

In communications, satellites promise to provide a superior means of broadcast of television or radio signals. Relay stations to send television signals across the oceans might be set up in a series of satellites. Such a television linkage would bind the earth together in a way that has not been achieved by other means of communication. A single satellite traveling at about half the speed of those already launched, but at an altitude of more than 20,000 miles, might, if properly directed, be placed so that it would move around the earth so as to stay continually over the same spot. Such an artificial star, as an aid to navigation, could make long-range travel accurate and safe. And in map making, a satellite of known orbit might help man reduce the uncertainty of a few hundred feet of the distances between the continents.

Earth as Seen from Satellite

Conflicting opinions have been given of the value of a satellite for observing details of the surface of the earth from outer space. One American project, according to some reports, plans to launch a satellite carrying television or infrared cameras to study the earth along with electronic devices to send the information back to ground stations. As to the potential value of satellites in world affairs in the near future, James R. Edson, assistant to the Director of Research and Development of the Army, offered this prediction in the *Bulletin of the Atomic Scientists* of March 1958.

"First, the skies of the world are irretrievably open. The Soviet leaders have been coy about our 'open skies' proposal; and we ourselves may not have been quite ready to peel open the skies of all the world, as the Russian astronauts have now in fact done. A satellite of 'muttnik' payload capabilities [some 1,200 pounds], suitably equipped, can be a potent surveillance device. It could

(so crystal clear is empty space) gaze down into your yard, and send back to its master a picture of your car standing in your driveway. Within the next year or two, we should expect the beginnings of such surveillance.

"The owners of such devices can watch in some detail the shipping, building, industrial and military activities of the world by optical and electronic means.

"What will it be like to live thus always under alien eyes? People everywhere may come to welcome the friendly shelter of the clouds. Perhaps the world will prefer to keep these eyes in the sky under international sponsorship, passing from an International Geophysical Year scientific phase to a United Nations surveillance satellite era. At any rate, so far as open skies can do it, the world will soon be forever nakedly innocent of secrecy—or privacy, for that matter!

"Spy in the Sky"

"A surveillance satellite is a spy in the sky. Every nation is now a potential producer of antisatellite weapons. Their use will be affected by two conflicting factors: on the one hand, nations will want to control in fact (and in law) the space above them; for this, they must be able (and willing) to destroy intruding satellites. But, if they burn out their rival's satellite eyes, he may launch a 'preventive' attack.

"Of course, if satellites come under attack they will get defensive arms and armor. It is not clear whether armed satellites will become important strategic bombardment weapons; but, equipped with appropriate surveillance means and weapons, they will be able to detect and destroy hostile ICBM's, or new satellites, while these are still rising under power above their launching bases. (This would be a very punishing experience for the countryside around the bases!) Such an anti-ICBM satellite system can and may be a reality within a decade."

Which Route Shall Man Travel in Space?

World affairs will be shaped by satellites in the future as certainly as they have been shaped by other major historical events. Some of the possibilities can be suggested, although the course of events cannot be predicted. Will satellite developments come in a peaceful spirit of scientific conquest or as part of a military race? Will international cooperation, notably through the UN, or international conflict, guide man's future steps from the primitive satellite to a man-carrier capable of traversing 240,000 miles to the moon? And which of these approaches will lead man's travels through our solar system and perhaps beyond our solar system to the nearest stars?

For the big fact the satellites have taught the world is that man is no longer bound by gravity to the earth. He will soon—perhaps as soon as a decade or two in the future—travel in space as the great navigators traveled the seas to explore the planet 500 years ago. Even a primitive satellite can be a staging point for a giant step into space. Rockets capable of driving a half-ton payload at 18,000 miles an hour are little short of the rockets needed to reach 25,000 miles an hour, the "escape velocity" at which travel forever beyond clutch of the earth's gravitational pull is possible. Scientists are confident that the problems of food and air and protection against heats that boil the blood and colds that freeze it can be solved.

A few tens of thousands of years ago man lived in fear and trembling in a cave. He ventured warily at night, prey to wild animals, and if he lifted his eyes to the stars he saw them with little more curiosity than a beast. The gift of intelligence has changed this in a time that is little more than an eye-wink in the 5 billion-year history of the universe. A man who looks at the night skies now can wonder if his children or his children's children will travel there. What will be found in this voyage of exploration, the greatest man has ever started?

Discussion Questions

1. What is the significance of earth satellites in time of peace? In time of war?

2. How can a satellite speed up or slow down without using rockets?

3. How high does the earth's atmosphere extend?

4. Where do cosmic rays come from?

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VISUAL AIDS

A Trip to the Moon. Produced in 1957 by Encyclopedia Britannica Films. 16 min., Color. Rental, $5.50 from EBF offices: 1144 Wilmette Avenue, Wilmette, Ill.; 202 East 44th St., New York, N.Y.; 1414 Dragon St., Dallas, Texas; 5625 Hollywood Blvd., Hollywood, Calif.; 277 Pharr Road, N.E., Atlanta, Ga. Aboard an imaginary rocket conditions to be met in navigation during a trip to the moon are explained. The film combines animation and model photography to create a realistic illusion of a study of the moon's surface.

Russian Rocket to the Moon. Produced in 1958 in the Soviet Union. 5 min. Rental, apply Brandon Films, 200 West 57th St., New York 19, N.Y. Animated film depicting Russian view of how the first flight to the moon might work. Shows the use of an unmanned baby tank for the exploration of the moon's surface plus other techniques for getting to the moon and exploring it.

In spite of the popularization of science in the United States, we are still apt to think more about the potential for destruction of new discoveries such as fission and fusion than about the constructive contributions science makes and can increasingly make in the future to the welfare of all mankind. Yet it is in this direction that scientists are opening up exciting new frontiers.

Science and Human Welfare

by Robert C. Toth

In a recent issue of *Punch* there appeared one of the biting cartoons typical of that humor magazine. It showed a toastmaster rising and introducing the after-dinner speaker with the presumptuous words: "The learned professor will now discuss for us the peacetime uses of the intercontinental ballistic missile."

Ironical as it may first seem, this is undoubtedly the single most important job that science can do today for human welfare—to emasculate the crouching, deadly symbol of war and turn it into peace. Science made the frightening beast. For the sake of the advanced, as well as the backward peoples of the world, it must now unmake it.

Sooner or later the hydrogen-bomb tip of the ICBM must be dismantled. Within a generation, its hydrogen can be put to work generating electricity to meet the world's energy needs. The rocket itself can be sent off into the nothingness of space to search for basic knowledge about man, his beginning and his end, and the environment in which he lives.

Battling Hunger and Disease

However, it must be said that even now, without pacifying the ICBM and eliminating all war, science can aid the underdevel-

oped nations by battling two other terrible Horsemen of the Apocalypse: disease and hunger.

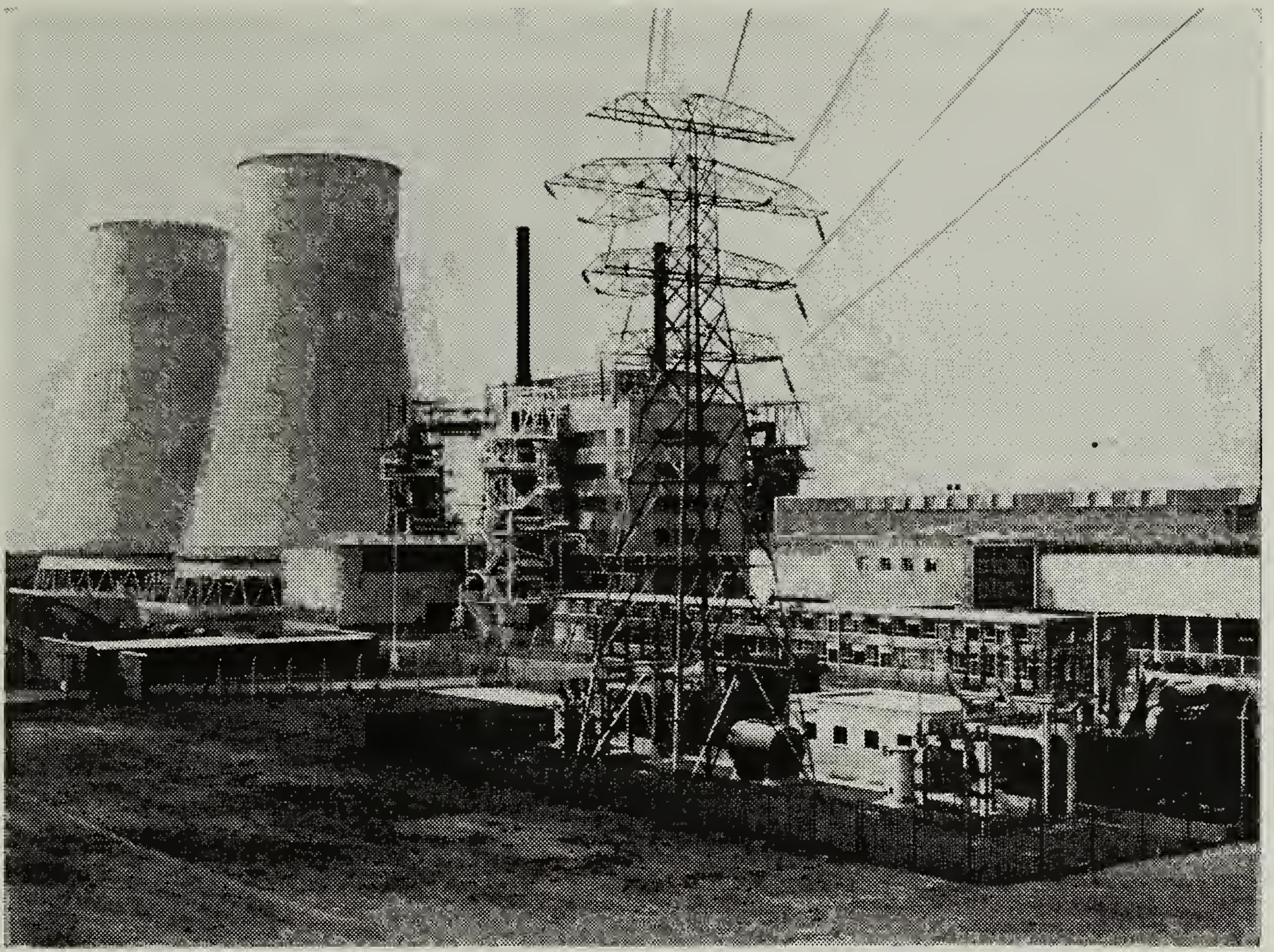
Most of the diseases that now plague the poorer nations can even now be conquered by medicine. Significantly, "health" has now come to mean, not just the absence of disease, but the physical, mental and social well-being of the world's peoples.

Hunger can be overcome through the scientific cultivation and distribution of the world's present supply of food, which today is more than enough for its population in spite of the fact that more than half of that population goes hungry each day. Science can show the best way to supplement diets that may be deficient in vital constituents. And when the time comes, science should be able to grow synthetic food—but first it must learn the answer to the esoteric question, What makes the grass green?

Need for Nuclear Energy

Most areas of the world need more fuel to generate more power than they now have. Few are as wealthy as the United States in waterfalls and in the fossil fuels of coal and oil. Power from nuclear energy is science's answer to these energy needs. Even in the highly civilized nations, conventional fuels will last only another 1,000 years at the current rate of consumption. And, of course, that consumption rate is rising dramatically in every country as industrialization takes hold, while the existing deposits of coal and oil tend to become more difficult to tap. In our own country, nuclear power will become economical about 1970, experts estimate, and by 1990 it will be a necessity.

Nuclear power, as we know it today, is extracted from the nucleus, or core, of atoms by two methods. The first is fission, the atomic bomb reaction; it consists of the fissioning or splitting in two of such heavy elements as uranium and plutonium. The second is fusion, the hydrogen-bomb reaction; it consists of fusing or joining together two nuclei (or cores) of such elements as hydrogen, or double-weight hydrogen (called deuterium) or triple-weight hydrogen (tritium).



Courtesy of British Information Services

CALDER HALL, ENGLAND — This first large-scale atomic power station in the world was opened in 1956 to produce electricity for homes and factories in Britain

What Fission and Fusion Can Do

Raw materials for the fission process are somewhat more widely distributed around the world than the fossil fuels. India, for example, has good deposits of thorium, an element that can be easily converted into uranium, but little of the coal and oil vital to today's power plants. Uranium can even be leached out of granite. One pound of uranium will do the work of 1,300 tons of coal or 360,000 gallons of gasoline.

Fission reactors in all sizes, from large to portable, are ready today to help underdeveloped nations. With a minimum of daily fueling problems they could generate the power to irrigate deserts or evacuate swamps, clear jungles and build roads, drive

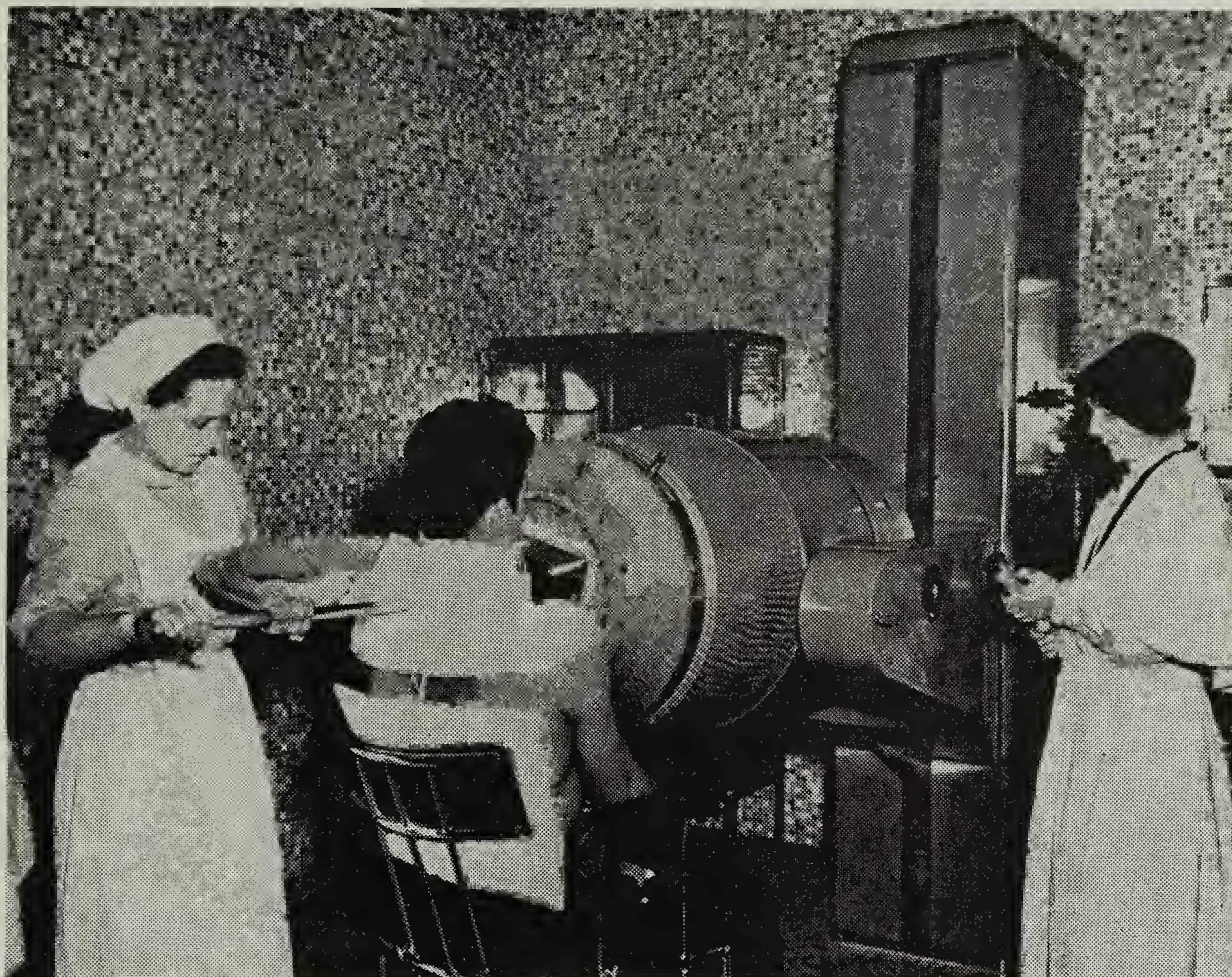
machinery and light homes. Even bombs could be put to use, blasting tunnels and digging harbors with their terrible explosive force, as indicated by Russian experiments and by our own 1957 underground tests in Nevada. It was suggested a few years ago by a special United States atomic energy advisory group that we build reactors in friendly underdeveloped nations, both to provide energy for their advancement and, selfishly, to gain experience with the infant nuclear reactors before we use them domestically. But nothing ever came of this proposal.

There is a limit, however, to the amount of fissionable material around. Experts calculate that the world would run out of it within 200 years. At present, the ultimate answer of science to the world's energy problem is fusion power, the power that now comes only from the stars and hydrogen bombs. The mere five pounds of the hydrogen in an ICBM warhead will supply enough electricity for New York City for one day. This heavy hydrogen comes from water—any water, salt or fresh. Five pounds of heavy hydrogen are found in every 300 gallons of water, and even today the cost of extracting it is less than $5.00.

The fusion reactor's raw materials then are cheap, easy to extract and plentiful—in fact, plentiful in the extreme. They can take care of 1,000 times the world's present needs for the next billion years. The reactor should be perfected within 20 years.

Diseases Decline —

The medical and health sciences within the past decade have drastically reduced the diseases that plague the backward nations. The dread specters of tuberculosis, yellow fever, malaria, cholera, typhus, smallpox, plague and other major scourges have shrunken to puny shadows of their former selves. Their breeding grounds are cleaned up by sanitation and pest control, their spread is checked by protection of food and water supplies, their attacks are blunted by widespread use of vaccines and their toll is minimized by the antibiotic drugs. Much, of course, remains to be



Courtesy of the United Nations

Radioactive cobalt in a therapy unit of Canadian design, the first unit to be installed in Italy, is used for cancer therapy

done, particularly in the nations attacked by insidious diseases that unobtrusively sap the strength of the population. Many doctors are convinced that disease, rather than inherent attitudes, causes the tropical peoples to be less productive than those in the more temperate climates.

Aiding these nations to control disease can pay dividends at home. Each time a country is rid of a health hazard, Americans are also a little bit safer. No nation is insulated from another, for disease knows no national boundaries, particularly in this age of air travel. One illustration may suffice to prove this point:

In 1947, a man dosed with barbiturates and aspirin for what he thought was only a splitting headache, made the long bus trip from Mexico to New York. On arriving he collapsed and died. Health officials learned he had smallpox. A terrified city mobilized doctors and nurses, armed with vials of vaccines to ward off a threatened epidemic from the germs carried by one man. Millions of dollars were spent in inoculating workers. Happily, no one else came down with the disease.

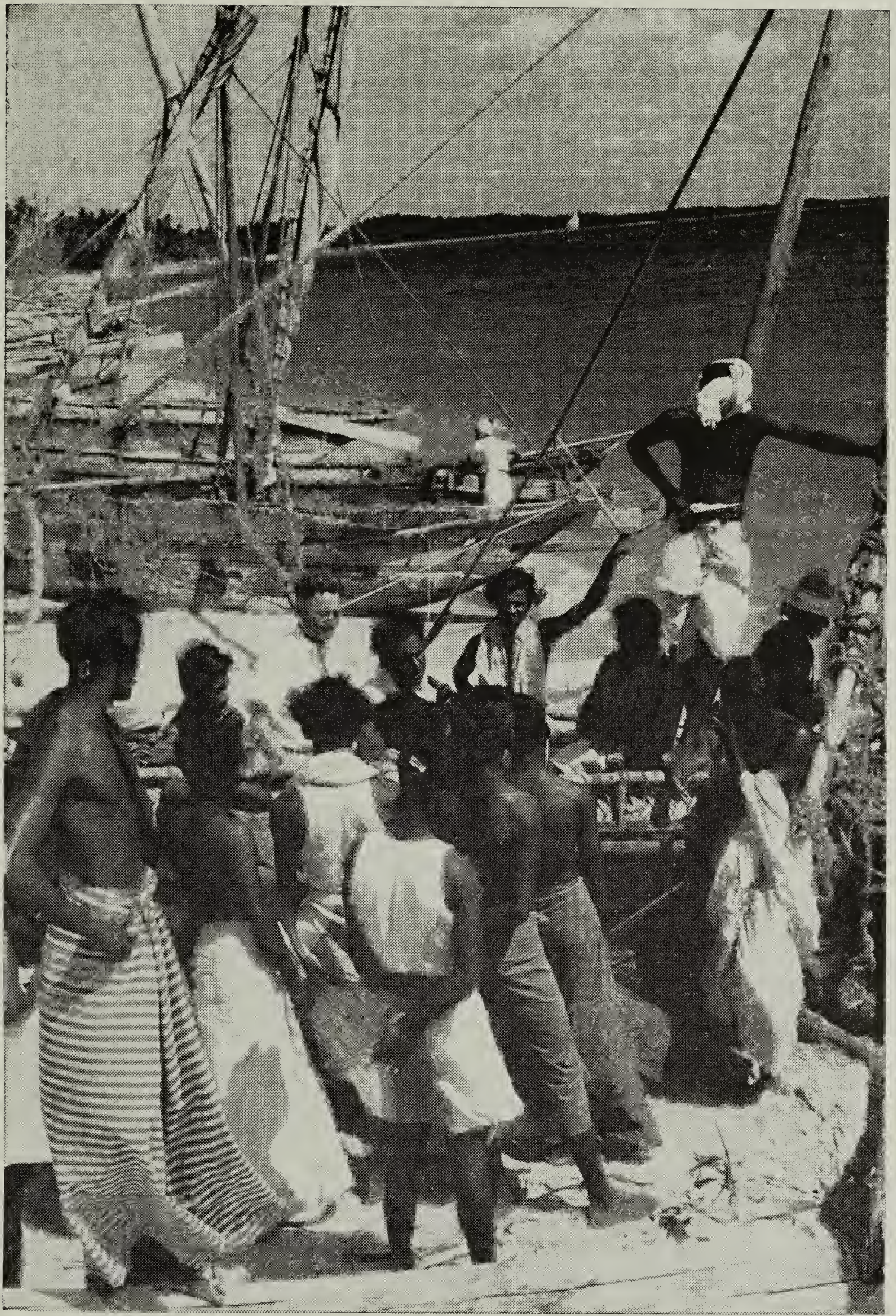
— But Populations Grow

However, control of disease in the underdeveloped nations has brought with it the grave problems of expanding populations and shrinking rations. People are living longer, thanks to medicine, while the world's over-all birth rate remains substantially the same. As a result, there are now more people on earth than ever before. The tide of population is rising; and more important, it is rising at an ever increasing rate. Food production, meanwhile, has increased at only half the pace, so most of the world's people are eating less today because of this flood of humanity.

There are now about 2.6 billion persons in the world. The United Nations calculates that we are multiplying at the rate of 1.3 percent each year. By 2000 A.D., then, the earth's population should double. By 2050 A.D. it should double again to more than 10 billion persons.

Much of the frightening population rise has occurred in the less-developed nations, where the decline in death rate, thanks to disease control, has been greatest. For not only are adults surviving longer, but the adult females are being given more time to produce babies. Most informed scientists are convinced that some form of birth control will have to be instituted in these areas, at least until the nations become sufficiently developed to support those persons already living.

Science has devised birth control methods that are effective. It is on the verge of introducing perhaps the simplest of contraceptive devices—a pill—but more tests are needed to insure the safety of



Courtesy of the United Nations

On Ceylon's east coast an FAO expert (facing camera, at left) discusses fishing techniques with local fishermen

its action. At this writing, the only complaint is that the pill must be taken daily, which is too great an undertaking for primitive women. The target is a pill that must be taken once a week, and it seems only a matter of time before this becomes possible.

Better Use of Food Needed

Science is also attacking the problem of feeding these billions. More than half of the world goes hungry each day, another quarter is undernourished, and about 100,000 new mouths come to the world's table each day—but food production has risen only half as fast.

All our food is made through the process called photosynthesis, by which green plants utilize the energy of sunlight to manufacture carbohydrates from carbon dioxide and water. These plants become our food, directly or indirectly. Science still does not know the intricacies of photosynthesis, nor can it duplicate it in a test tube. Once it unlocks this secret—that is, finds out why the grass is green—food can be synthesized.

Today, however, the world does not need to resort to synthetic food. About 150 tons of natural food is produced for each person each year, but we need only 0.3 tons to live well. The rest is wasted, either by nature or by the inefficiencies built into our diets. Enough photosynthesis occurs on this planet to support 500 times its present human population. But all except 10 percent of that goes on in the oceans in the upper layers of water where light penetrates—nourishing plankton, algae and like forms of life—and where it does little good for man. Then, too, man confines his food to cultivated land plants and to animals that feed on cultivated plants.

Further inefficiencies crop up. Animals pass on to us only one-tenth of the food they eat, and we ourselves use only a fifth of the plants available to us. This all means that we benefit from only two-tenths of one percent of all the food generated on earth. And coupled with the inequalities in the distribution of land fit for crops, this brings about the terrible gnawing hunger felt by more persons than not around the world.

What Science Can Do

Science now can give these hungry peoples advice on the most nourishing foods, on how to supplement diets to prevent disease, on how to prepare different vegetables to retain the greatest food value, and so on.

And science can also provide the farmer with information on crop rotation, on highest yield crops for different soils, on the best fertilizers, on use of machinery, on storage and the host of related avenues toward greater food production. New land can be cleared for farms, pests and parasites that reduce yields can be destroyed, hybrid crops best suited for certain soils and climates can be developed.

Finally, science can help in building a better society in the less-developed nations. Man's traits and qualities are products of his heredity and environment. While biologists are working on heredity, the social scientists and the psychologists have some good ideas about the pitfalls to avoid in family and community life. If given a chance, these various experts can help infant nations avoid some of the social conflicts that have marred the history of all civilized nations to date.

Science may not be permitted to do all these useful things for underdeveloped peoples, either for lack of funds or personnel, or politics, or a combination of all these factors. But these things can be considered our goals. For, as Robert Louis Stevenson said: "To travel hopefully is a better thing than to arrive."

Discussion Questions

1. Will Malthus' prophecy of 200 years ago that population growth will outrun food resources if positive or preventive checks are not applied prove true of underdeveloped countries in the 20th century?

2. Are there political and economic reasons why surplus food produced by the Western nations is not used to feed the hungry in non-Western lands? If so, how can these conditions be changed?

3. How can "the population explosion" in non-Western lands be checked?

4. What can the United States do to help the underdeveloped countries acquire the atomic power they need for development?

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VISUAL AIDS

The Petrified River. Produced in 1956 by the U.S. Bureau of Mines. 28 min., color. Rental, free, from Modern Talking Pictures Service, 21 West 60th Street, New York, N.Y. In addition to emphasizing the peaceful uses of atomic energy in industry, biology, medicine, agriculture and as fuel, it depicts the geologic history of uranium and shows present-day prospecting and mining of uranium ores and the atomic reactor at Oak Ridge.

The War on Want. Produced in 1954 by the National Film Board of Canada. 15 min. Rental, $3.00. With emphasis on the need for more food, the film depicts the economic problems of Southeast Asia and indicates how aid is put to use. Particular examples used are from the operation of the Colombo Plan.

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by Hans Kohn